Validation of the range-wide soil respiration models with continuous observations

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Abstract

The estimation of NEP across the PINEMAP domain requires range-wide estimation of heterotrophic respiration, which in turn is derived from total soil CO_2 efflux. However, understanding of range-wide variability and its main controls is limited, and only few studies have analyzed its dynamics in a systematic manner. Yet, even those studies have relied on instantaneous soil surface CO_2 efflux measurements, and contain significant uncertainties about temporal variability. Here we report the performance statistics of the models first developed by Templeton et al. (2015) and Gough et al. (2005) at four different loblolly pine stands where soil CO_2 efflux was measured for multiple (2-10) years. Broadly, the regional models developed on instantaneous growing season flux rates significantly overestimate the fluxes observed with continuously running autochambers. Model performance, and the options for correcting for the bias are explored.

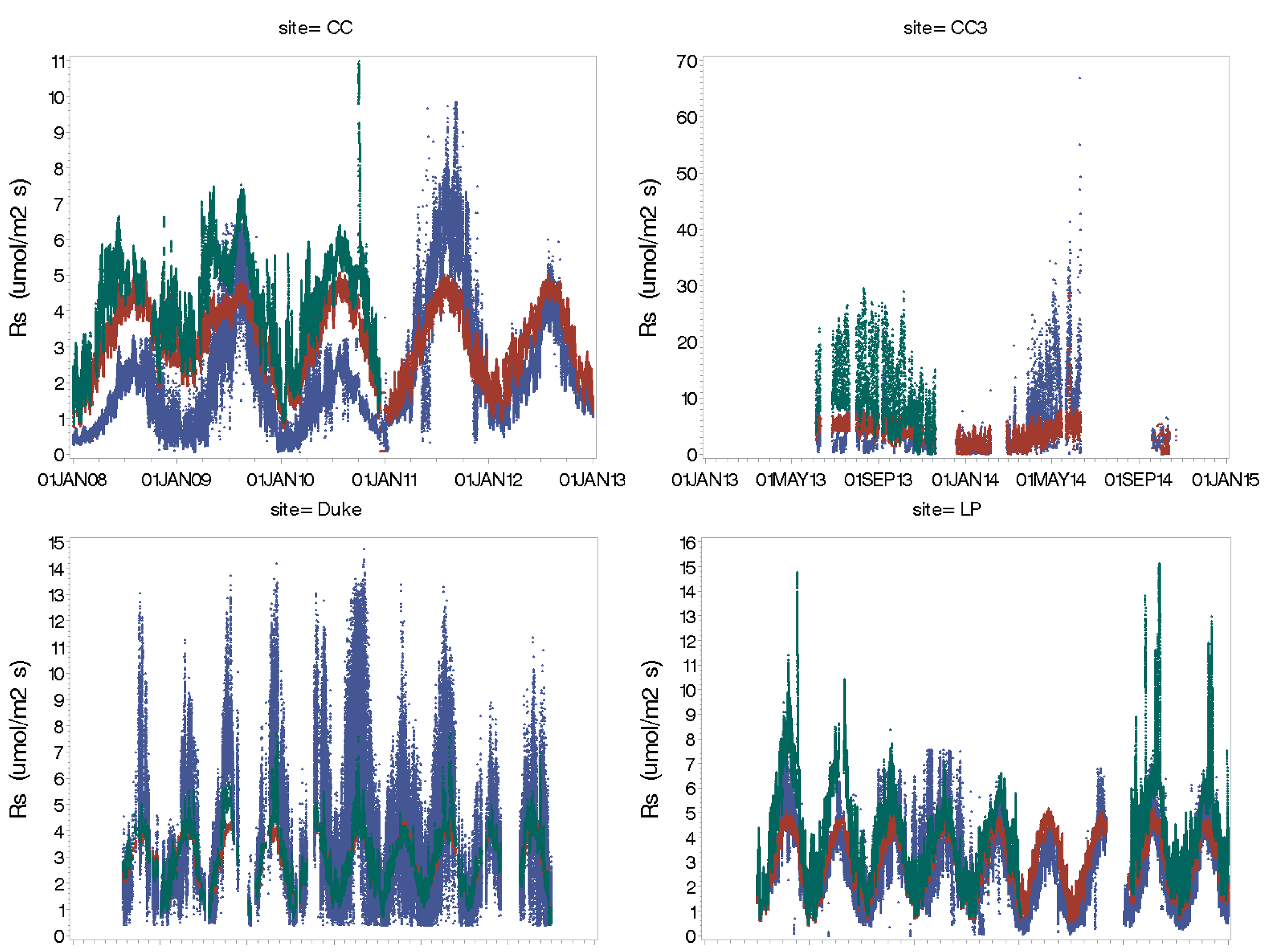

Figure 1. Measured and simulated soil surface CO_2 efflux (Rs) at four sites with continuous autochamber measurement systems. Observations in **blue**, Templeton et al. (2015) 1-parameter model in **brown**, and Templeton et al. 5-parameter model in **green**.

Background

Upscaling soil surface CO_2 efflux (soil respiration, Rs) to the PINEMAP domain is an essential step in the derivation of NEP estimates from observed and simulated NPP values. Although numerous studies have explored the variability and controls of Rs over recent decades, the transition from site-specific parameterization to a workable regional model has been elusive. To address this, Templeton et al. (2015) set out to fill this knowledge gap. They visited 154 plots in operational loblolly pine plantations throughout the SE-US, and measured Rs. These instantaneous measurements, collected over the course of two growing seasons were used to derive the subsequent 5-parameter (5P) multivariate regression model:

$$R_S = \exp(0.852 \times \log(Ts) - 0.045 \times lat + 0.576 \times N_{soil} + 0.089 \times Ts \times M - 0.336 \times BD + 0.483)$$

and a simplified 1-parameter (1P) model:

$$Rs = \exp(0.941 \times \log(Ts) - 1.482)$$

Across the domain, the models had coefficients of determinations of 0.56 and 0.45, respectively.

The current study was set up to evaluate the performance of the range-wide models at individual sites with continuous autochamber measurements. The key site characteristics are given in Table 1.

Table 1. Long-term soil respiration monitoring sites used for testing the range-wide soil CO_2 efflux model (Templeton et al., 2015).

Site name	Duke Forest Control	US-NC1 CC	US-NC2 LP	US-NC3 CC3
Species	Loblolly pine	Loblolly pine	Loblolly pine	Loblolly pine
Stand establishment	1983	2005	1994	2013
County	Orange, NC	Washington, NC	Washington, NC	Washington, NC
Latitude	35.97	35.8118	35.8030	35.8030
Longitude	-79.10	-76.7119	-76.6687	-76.6687
Soil series	Enon	Cape Fear	Belhaven muck	Belhaven muck
Data coverage	2001-2010	2005-2009	2006-2013	2013-2014
R^2 of Templeton model	60% (38…86)	58% (49…65)	63% (43…73)	36% (33…50)
Mean bias (umol m^{-2} s^{-1})	0.62±1.83	-0.98±2.15	-0.36±1.93	1.07±2.0
Interannual range (umol m^{-2} s^{-1})	1.9	3.2	2.4	n/a
Soil N (%)	0.07	0.31	0.31	0.31
Soil bulk density (g cm^{-3})	1.27	1.07	1.11	1.11
Ts (°C, mean & range)	14.4 (2.0…25.0)	16.4 (0…27)	15.9 (1.9…28)	18.2 (-16…47)
VWC (%, mean and range)	0.26 (0.13…0.54)	0.23 (0.1…0.53)	0.26 (0.07…0.7)	0.43 (0.37…0.53)

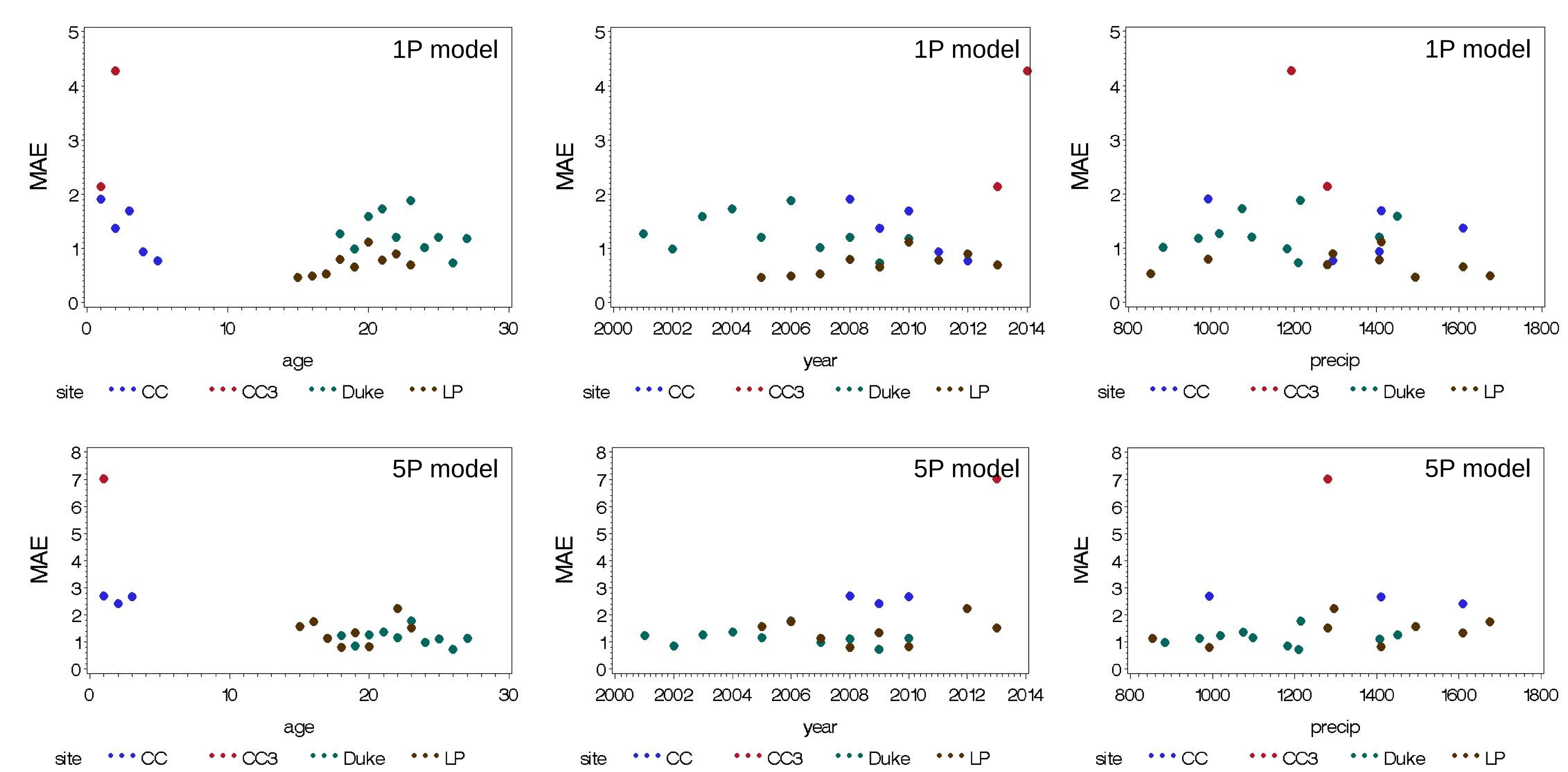

Figure 2. Mean absolute error (MAE) of the 1-parameter (1P) and 5-parameter (5P) models on instantaneous flux basis as a function of age, year, and annual precipitation.

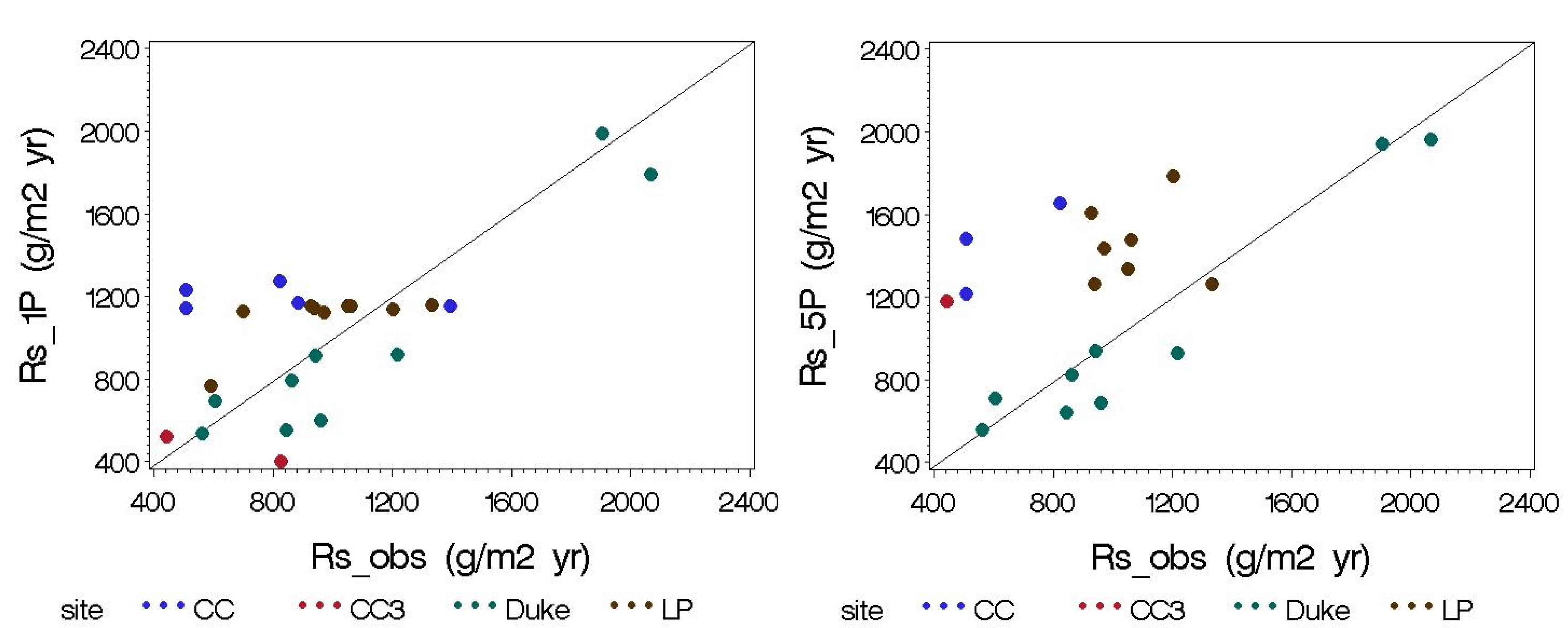

Figure 3. Modeled versus observed annual soil CO_2 efflux estimates. R^2=0.58 for 1P model, and R^2=0.38 for 5P model.

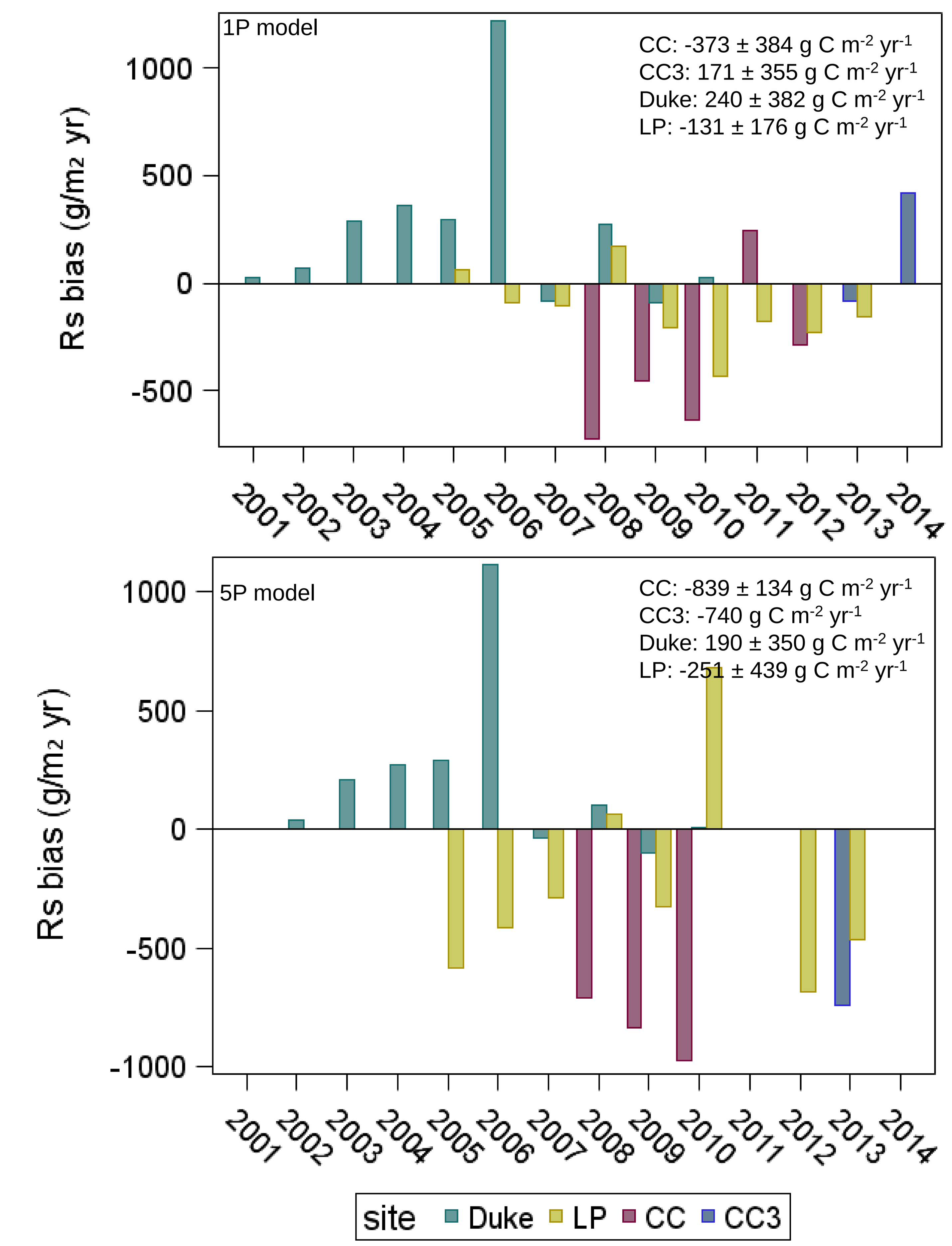

Figure 4. Annual flux bias of the 1-parameter range-wide model.

Summary

1. The Templeton et al. (2015) models appear to work satisfactorily in the mid-to late-rotation closed canopy stands, but not in young, recently disturbed stands.
2. The simplified 1P region-wide model was more consistent and conservative across sites than the 5P model. Yet, the 1P model could not resolve the at times significant interannual variation, and showed significant bias at young stands.
3. While the 5P model captured more of the interannual variation at individual sites than the 1P model, it also exhibited greater sensitivity to high VWC than evident in observations.
4. Despite at times significant deviations of model estimates from observations, both 5P and 1P models exhibit similar performance statistics with site-level integrated fluxes as reported in the original analysis.
5. No residual correlation were detected between model bias and site characteristics like site index, soil bulk density and soil N content. Adding age to the range-wide model may potentially increase its performance.

References

Templeton BS, Seiler JR, Peterson JA, Tyree MC (2015) Environmental and stand variables influencing soil CO_2 efflux across the managed range of loblolly pine. *Forest Ecology and Management*. http://dx.doi.org/10.1016/j.foreco.2015.01.031

PINEMAP

United States Department of Agriculture National Institute of Food and Agriculture